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THE TRENTON, N. J., FILTRATION PLANT

By F. W. Daggett

For a great many years Trenton has taken its supply of water from the Delaware River. The territory above the city, while not as densely populated as that below, still has many large towns and small cities, all of which discharge their sewage directly into the river. In very few cases is this sewage given any preliminary treatment. At times of flood, the Lehigh, the Delaware's largest tributary above Trenton, brings down great quantities of fine coal dirt from the anthracite washeries along its banks. At such times the Delaware at Trenton, 50 miles below the mouth of the Lehigh, is often the color of writing ink. At other times it is the color of coffee due to wash of the clay banks immediately above the city.

With these facts in mind, one is not surprised that for at least twenty-five years various projects had been proposed for improving the water supply. Most of them recommended filtration of the river water. Examinations of the sub-surface conditions surrounding Trenton had proven that very little could be expected in developing an adequate supply from artesian wells.

This view was supported by Mr. Allen Hazen, in 1900, in his very complete report on the purification of Trenton's water supply. Mr. Hazen recommended filtration of the river water, and suggested five different projects. Three of them used the slow sand method of filtration, while the other two were rapid sand or mechanical types of plants. Mr. Hazen favored one of the slow sand projects. Owing to its high initial cost, and also to the fact that this project proposed to convert the newly completed distribution reservoir into a sedimentation basin, Mr. Hazen's recommendation was not received favorably by the water board.

For the next ten years very little was done. In 1910 typhoid fever was very prevalent in the city, the polluted water supply being undoubtedly the principal source. In 1911 the city adopted government by a commission, and abolished the old political water board. The water department then came under the direction of

Mr. J. Ridgway Fell, Commissioner of Streets and Public Improvements. Mr. Fell had formerly been city engineer and realized that something else than talk was needed to conserve the health of the city. He put the matter in the hands of Mr. George A. Johnson, consulting sanitary engineer of New York. Mr. Johnson, recommended that the city build immediately a sterilizing plant to disinfect the water by the use of hypochlorite of lime, to be followed a few years later by rapid sand filtration. This suggestion was adopted, and within six months after the commission government took hold, the sterilizing plant was put in operation. The deaths from typhoid in the year following decreased over one-third. This decrease has steadily progressed ever since, and in 1916, with complete filtration as well as sterilization, the deaths from typhoid are only 15 per cent of what they were in 1911.

Work on the filtration plant was started in January, 1913, and it was put in operation in November, 1914. It is located on the river bank about 300 feet upstream from the pumping station where both the high and low lift pumps are placed. There are two of the latter, each with a capacity of 20,000,000 gallons daily. They are of the centrifugal type driven by 220-volt direct-current motors. A constant water level is maintained in the sedimentation basins by means of a float which controls the field of these motors and thereby their speed. The electric power is generated by two 200-kilowatt DeLaval turbo-generators, one of which is always in reserve.

The filtration plant was designed to handle 30,000,000 gallons per day. At the time the plant was being built the average daily consumption of the city was over 20,000,000 gallons. Since then, owing to pitometer surveys and to an increase in the number of metered services, the consumption has been reduced to an average of about 17,000,000 gallons per day.

There are two sedimentation basins, each with a capacity of 2,000,000 gallons. Either one or both may be used, thereby varying the period of subsidence to suit conditions. The water on entering, after being treated with a coagulant, is evenly distributed across one end of the basin by means of weirs and baffles. This prevents eddies and cross currents, and gives a minimum entrance velocity to the water, which secures very favorable conditions for the rapid subsidence of the suspended matter. Owing to restricted area, the basins were made 20 feet deep. It was expected that they would not be as effective as a larger and shallower basin, but experience has shown them to be able, with the proper alum dosing, to remove from 60 to 80 per cent of the turbidity.

As the basins cover less ground space than is usual for basins of their capacity, the depth of mud accumulated is quite great. After a year's run, it is often 6 feet deep at the inlet end, tapering off to about half that at the outlet. There is also a marked difference in its consistency. As one would expect, the material at the inlet end is heavy and coarse, with a large amount of sand, leaves and such material. As the floors of the basins are at about the elevation of the normal river level, all the sludge has to be pumped out. In each basin there is a pump designed to handle about 15 per cent of mud or sand when mixed with 85 per cent of water. If these figures are exceeded and the pump becomes clogged, the direction of rotation of the impeller is reversed and a water jet opened into the casing. These means rarely fail to clear the impeller of all obstructions except leaves, small twigs, sticks and the like. Such things must be kept out of the pump unless they are made small enough to pass through. To accomplish this, the pump was enclosed by a fence 2 feet high of ¾-inch copper screen. A fire hose is played on this screen, which is forcible enough to tear most of the leaves into small pieces, which can readily pass through both the screens and pumps.

The sixteen filter units are arranged in two rows of eight, and each has a normal capacity of 1,875,000 gallons per day, and a sand area of 652 square feet. The combined air and wash-water system is used. The strainer system is all cast iron pipes with brass strainers. The laterals are embedded in cement level with their tops. The strainers have a deflecting plate on the top which causes a downward flow of the wash water against the floor of the filter. This was expected to prevent any organic growths on the floor of the beds, and after four years operation none has been observed. The strainers have the trap tube feature common to many systems of this type, and which has proven most effective in ensuring a uniform air distribution.

The rate of washing is about 13 gallons per square foot per minute. This is about as high as it is possible to go with this style of filter bottom unless either larger gravel were used and more of it, or some means taken to prevent the gravel from being lifted. The whole washing system is very efficient, and the wash water used has averaged about 1.5 per cent. During 1918 it was 1.3 per cent. The author cannot recall any figures from the plants using high rate wash without air that are better than the above. Four years experience at Trenton seems to show that the air wash is really a wash water saver, and also has other advantages in aerating and stratifying the filtering medium.

The filter gravel is a foot deep and ranges in size from $\frac{3}{4}$ to $\frac{1}{8}$ inch. The filter sand had a depth of 30 inches when placed, but about 2 to 3 inches has been lost in washing. Three months after the plant was started, this sand had an average effective size of 0.45 mm. and a uniformity coefficient of 1.40. Two years later an analysis showed the average effective size to have increased to 0.53 mm. while the uniformity coefficient had remained practically constant at 1.38.

Sulphate of alumina is used as a coagulant, the average consumption being a ton a day. During high water stages there is a deficiency of alkalinity in the river water and soda ash is required to obtain proper coagulation. When in 1916 the price of alum went soaring, this plant was one of the first to install apparatus for making its own alum. The Hoover process, which was perfected at the Columbus filtration plant, is used here. As this process had not been developed when the plant was built, it had to be fitted in afterward as best it could, and the work has been handicapped in this respect. On this account the making of alum at the filtration plant has lately been abandoned, and a plant is now being erected which will have a railroad siding and other facilities for doing the work more economically. Acid will be purchased in tank cars, and possibly pulverizing machinery installed so that the less expensive grades of southern bauxite can be utilized.

In 1916, when commercial alum was selling for about $60 a ton, the Hoover process showed a saving of about $25 a ton. In 1917 and 1918 as the price of commercial alum dropped slowly, the saving was reduced to a minimum of about $8 a ton. Then the manufacture was discontinued for the reasons just stated. With the benefit of three years' experience, it is expected that the new plant will show a saving of from $10 to $15 on a ton, depending on the relative costs of commercial alum and sulphuric acid. Wholesale manufacturing methods, such as outlined herein, are found to be most effective in balancing increasing costs of labor, and thus keeping the total cost of operation at a minimum. It is found that the

Hoover alum gives results equally as good as the standard alums, but its higher percentage of insoluble material (12 to 15 per cent) requires minor changes in the chemical devices.

Outside the removal of turbidity, which occasionally gets as high as 2000 parts per million, the plant must cope with a water which is highly polluted with sewage bacteria at all times. Soon after filtration was started, liquid chlorine was substituted for bleach as a sterilizing agent. From 1½ to 2 pounds are added per million gallons of water. Samples of the effluent are tested for B. coli every four hours, and all tests are confirmed. Great care is taken to eliminate these bacteria, and duplicate chlorinators are always ready in case of trouble with the one in use. In 1918 the total number of B. coli tests made were 2267. Of this number only nine-tenths of 1 per cent were positive in 1 cc. and 2.8 per cent were positive in 10 cc.

During the winter of 1917–1918 great difficulty was had in getting an adequate supply of chlorine, owing mostly to transportation troubles. The cost of this material also seemed to the officials to be too great. It was decided to try out a method of making chlorine electrolytically from salt. Upon investigation by the author, it was found that there were only two filtration plants making their own chlorine; one at the Little Falls plant of the Montclair Water Company, used the Nelson cells, and the other at the plant of the Montreal Water and Power Company used the Allen-Moore cells. The latter was very completely described in a paper by F. H. Pitcher and J. O. Meadows, printed in the JOURNAL, volume 4, page 337. The Trenton plant is so similar that no detailed description will be given here. Both installations use the Allen-Moore cells, designed by the Electron Chemical Company, of Portland, Maine. A new 300 ampere cell was designed for Trenton, which is half the amperage of the Montreal cells. The four cells have a maximum output of 75 pounds of chlorine a day. The usual output is about half of this, and only two or three cells are in use most of the time. Each cell requires three and a third volts. The current is taken from the water works own 220-volt direct-current service, and reduced to the proper voltage by a motor-generator set at the filtration plant.

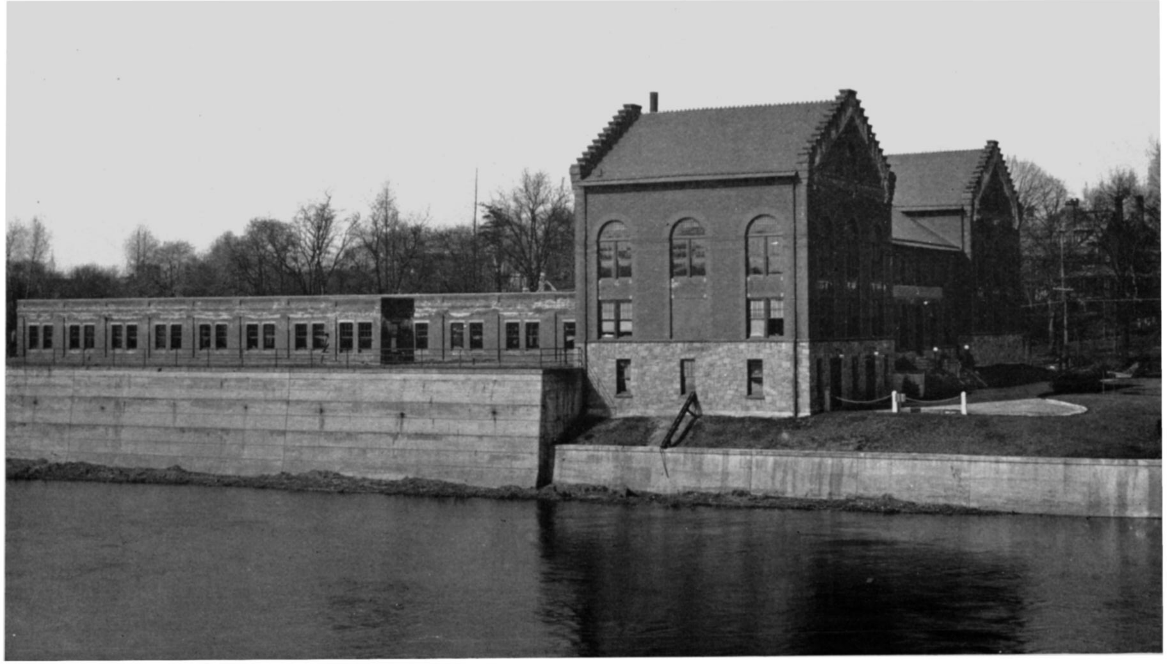
The amount of chlorine produced depends on, first, the amount of brine flowing through the cells, and second, the amperage. At Trenton the former is kept as nearly constant as possible, while the latter is varied to suit the pumpage. This method of control does not give as good economy of production as a constant current method would, but it is more accurate, and overdoses of chlorine, with a possible obnoxious taste, are avoided.

The plant was placed in operation in November, 1918, and is producing chlorine at a cost of 4.2 cents a pound exclusive of depreciation and investment charges. At that time the city was paying 17 cents a pound for its liquid chlorine. It takes about 4¾ pounds of salt and 1.6 kilowatt hours of electric current to make a pound of chlorine gas. At Trenton, as at Montreal, the effluent from the cells, consisting of undecomposed salt and caustic soda, is wasted, as the quantity produced does not justify its reclamation. In a larger plant it would pay to reclaim them in a marketable form; the salt to be used over again, and the caustic either sold or used in place of soda ash or lime. Such a plant could produce chlorine at very low cost. It would probably be very little more than the cost of the electricity required.

Table showing results of operation of the Trenton filtration plant for the years 1915 to 1918 inclusive

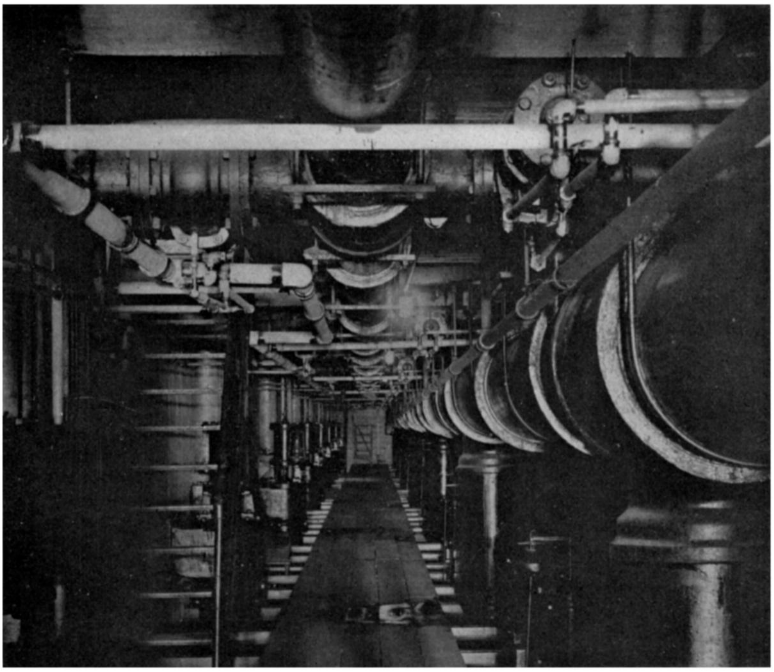
	1915	1916	1917	1918
Total amount of water filtered (M. G.)...	6276	5906	6081	6775
Average water filtered per day (M. G.)...	17.19	16.15	16.69	18.58
Average filter runs (hours)...............	35	42	48	43
Average percentage of wash water........	1.8	1.4	1.6	1.3
Average alum used (lbs. per M. G.)......	93	87	112	100
Average chlorine used (lbs. per M. G.)...	1.7	1.5	1.8	1.7
Average turbidity raw water............	57	18	30	29
Average turbidity filtered water..........	0	0	0	0
Average color raw water................	28	25	27	28
Average color filtered water..............	6	10	5	8
Average alkalinity raw water.............	26	25	24	23
Average alkalinity filtered water.........	20	21	19	19
B. coli; percentage of positive tests in 10 cc. filtered water	3.2	5.5	7.5	2.8

For eight years past Trenton has been sterilizing its water with chlorine, using three different methods: First, bleach; second, liquid chlorine; and last, electrolytic chlorine gas produced as required. Each step has marked a distinct improvement and in the last one the water officials feel that they have the most economical and efficient sterilizing equipment known at the present time.

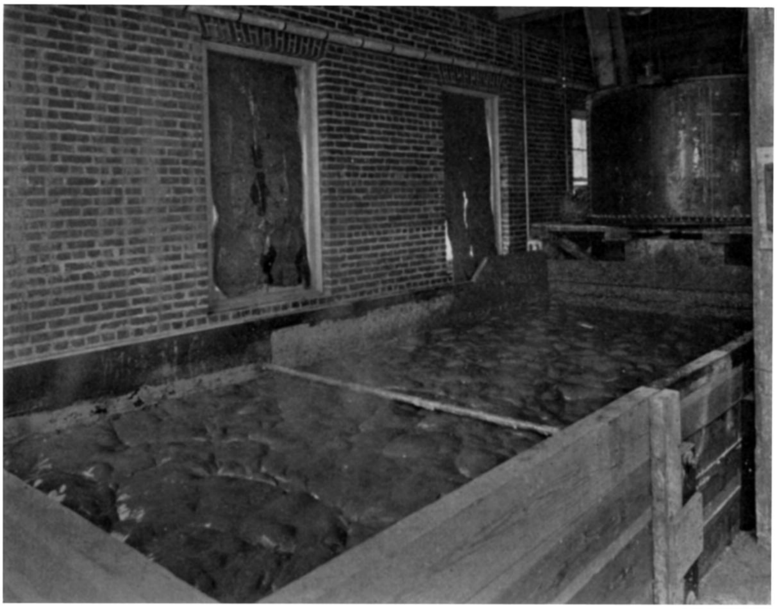


General View of the Water Filtration Plant at Trenton, N. J.

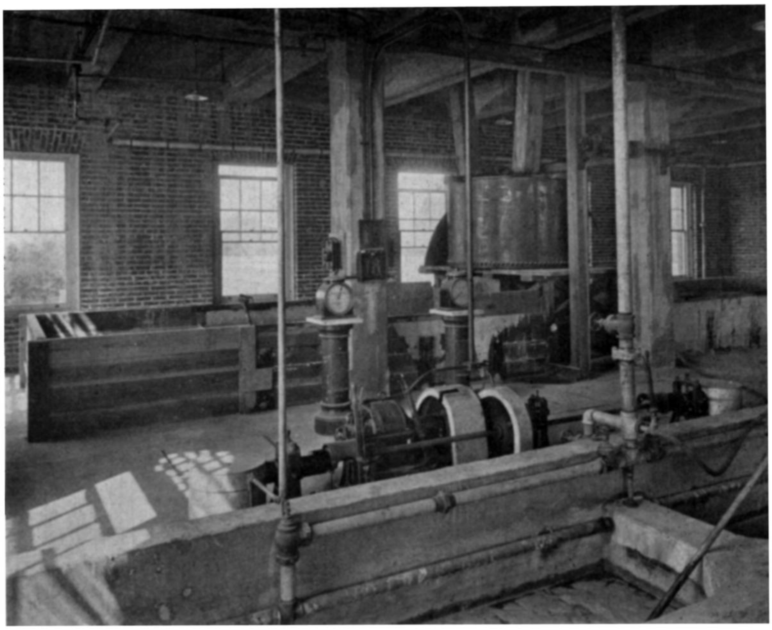
Interior of the Filter House



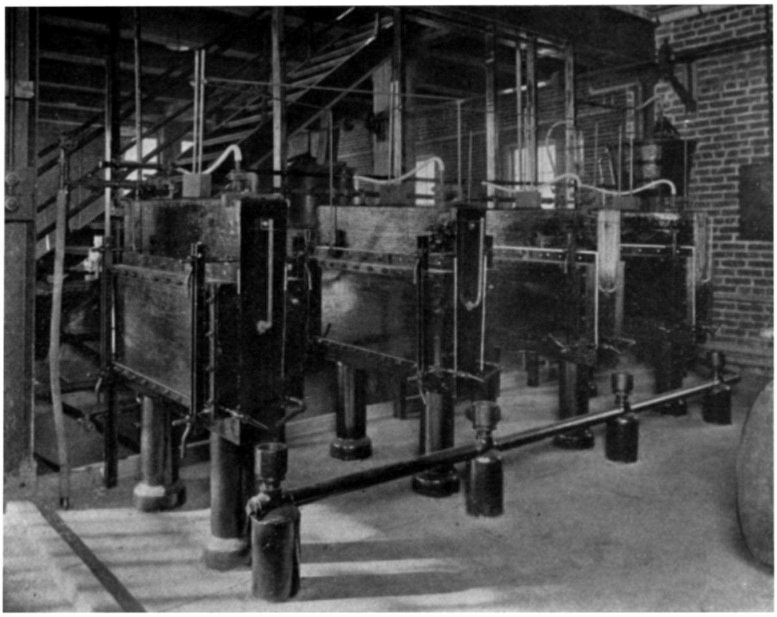
The Pipe Gallery



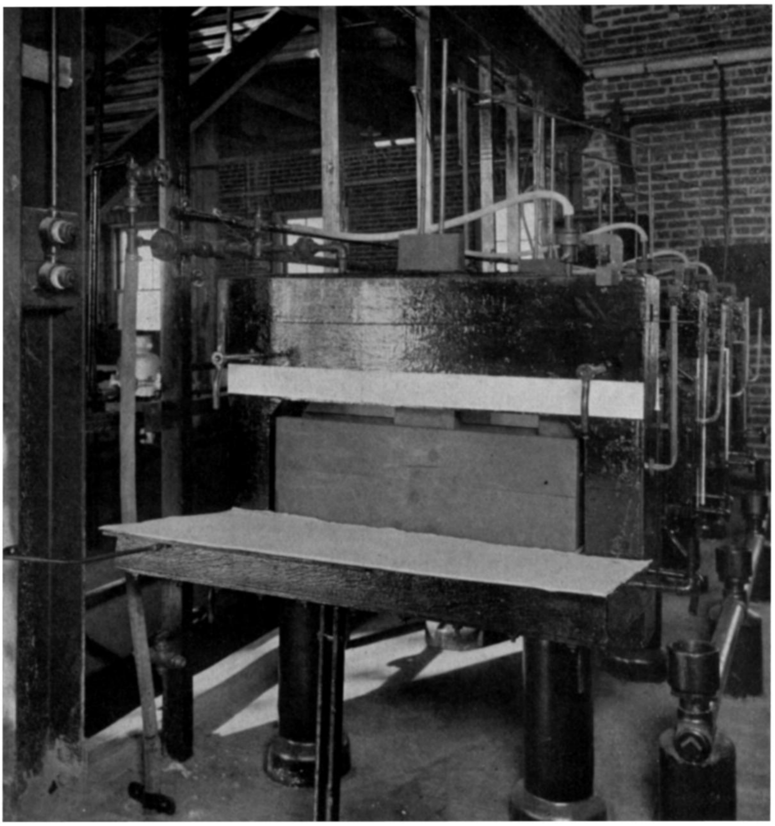
Alum Boiling in the Crystallizing Box



Apparatus for Making and Dissolving Alum



General View of Cells, Electrolytic Chlorine Apparatus



Interior of a Cell, Electrolytic Chlorine Apparatus